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# **Time-Dependent Countermeasure Considerations in Industrial Protection**

**L. Spogen**

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**Prepared for the Federal Emergency Management Agency  
Washington, D.C. 20472  
FEMA Interagency Agreement EMW-E-1452, Work Unit 2342D  
Final Report, May 1984**



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A countermeasure's effectiveness is also influenced by the level of protection needed by specific industries and the characteristics of those industries. An overview of basic interdependencies allows us to properly characterize the time dependencies existing in countermeasures.

Characterizing the time-dependent countermeasures also provides a means for describing essential program elements for the Protection of Industrial Capability (PIC) program, and for defining the information required for the PIC program's decision options. This report is a small part of that large integrated program. For an overview of the work performed at this laboratory, see report number UCID-20296 entitled Protection of Industrial Capability Program Pre-Decision Support.

Considerations in this report include: dispersal, survivability requirements for critical industries, enhanced recovery measures, the characterization of industries, and the characterization of countermeasures. Based on these considerations, this report also describes a general method for providing a required post-attack industrial capability at a minimum cost. However, the development and collection of detailed information is needed before the method can be applied.

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**DETACHABLE SUMMARY**

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Countermeasure Considerations  
in Industrial Protection**

**by**

**L. Spogen**

**for**

**Federal Emergency Management Agency  
Washington, D.C. 20472  
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# **TIME-DEPENDENT COUNTERMEASURE CONSIDERATIONS IN INDUSTRIAL PROTECTION**

## **Detachable Summary**

Protecting our industrial capability from nuclear attack may be done by employing various countermeasures intended to accomplish specific protective goals. Many potential countermeasures have previously been recommended without an appropriate consideration of their implementation times. A countermeasure's effectiveness in accomplishing a prescribed goal depends on the times when various actions associated with it are executed, and on the times required for their execution. We must therefore know about any time dependencies in the countermeasures.

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**LAWRENCE LIVERMORE NATIONAL LABORATORY**  
**University of California • Livermore, California • 94550**



## CONTENTS

Introduction . . . . .	1
Post-Attack Industrial Capability . . . . .	3
Estimation of Industrial Survival . . . . .	4
Determining the Hardening Requirements . . . . .	7
Dispersal and Recovery . . . . .	9
Selection of Industrial Countermeasures . . . . .	15
Technical Approach . . . . .	21
Conclusions . . . . .	26
Recommendations . . . . .	27
References . . . . .	28
Distribution List . . . . .	29



## LIST OF FIGURES

Figure 1.	Interdependencies in the countermeasure selection process .	2
Figure 2.	Two ways to obtain a given post-attack industrial capability, $Q_0$ . . . . .	3
Figure 3.	Estimating industrial survival . . . . .	4
Figure 4.	(a) The influence of the number of warheads on industry. (b) The influence of a defensive capability. (c) The influence of dispersal. (d) The influence of protection . . . . .	6
Figure 5.	Industrial survival as a function of kill radius . . . . .	7
Figure 6.	The process for determining overpressure hardening requirements . . . . .	8
Figure 7.	Example of Step 1. By using three specified parameters, we can find the allowable kill radius, $r_k$ . . . . .	10
Figure 8.	Example of Step 2. By using two specified parameters, we can find the peak overpressure hardening requirements . . . . .	11
Figure 9.	Survivability as a function of hardening . . . . .	12
Figure 10.	Other hardening requirements at a 16-psi overpressure from the previous example . . . . .	13
Figure 11.	Using dispersal to increase the allowable kill radius . . . . .	14
Figure 12.	Hardening costs as related to the planned survivable kill radius . . . . .	17
Figure 13.	Dispersal costs as a function of the planned survivable kill radius . . . . .	18
Figure 14.	Costs to increase survivability as a function of the planned survivable kill radius . . . . .	19
Figure 15.	Illustration of the concept by which countermeasures are selected . . . . .	20
Figure 16.	An example of a comprehensive countermeasure . . . . .	22
Figure 17.	Time phases in an attack scenario . . . . .	22
Figure 18.	A sample industrial characterization that would be used to identify the appropriate countermeasure . . . . .	23
Figure 19.	Countermeasure characterization for a specific industry . . . . .	24
Figure 20.	Factors evaluation for time-dependent countermeasures . . . . .	25
Figure 21.	Final selection of industrial time-dependent countermeasures . . . . .	26



# TIME-DEPENDENT COUNTERMEASURE CONSIDERATIONS IN INDUSTRIAL PROTECTION

## INTRODUCTION

Through an interagency agreement, Lawrence Livermore National Laboratory (LLNL) is assisting the Federal Emergency Management Agency (FEMA) in its Civil Defense Program. LLNL's efforts are mainly in the area of industrial protection, specifically pertaining to the needs of the Protection of Industrial Capability (PIC) Program. One element of LLNL's effort is entitled "Time-Dependent Countermeasures." This report describes the work accomplished in that element. This aspect of industrial protection is important because some effective countermeasures could be taken at moderate costs, but they would reduce our current capability. Some could be taken later during an international crisis; they might not work, but they would be inexpensive.

This report is concerned with the protection of our industrial capability from nuclear attack. Protection\* results from employing various means called countermeasures, where each countermeasure is intended to accomplish a specific protective goal. The effectiveness of a countermeasure with respect to its prescribed goal depends on when the various actions associated with it are executed and on the times required for their execution. It is therefore essential that we know about any time dependencies that exist in the countermeasures. Taking countermeasures either today or in the future would have enormous positive or negative legacy value in the future, depending on how appropriate they are.

However, the effectiveness of countermeasures is influenced by time, by the level of protection that is sought, and by factors that are characteristic of specific industries. The basic interdependencies that exist in the selection of an overall industrial protection scheme are suggested by Fig. 1.

This overview allows us to characterize the countermeasures' time dependencies. Careful examination of Fig. 1 not only permits identification of the important characteristics of time-dependent countermeasures, it also

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\* Complete protection implies protection against all of the nuclear effects. In this report, we have included only those measures directly related to blast and thermal effects. Although the effects of fallout and electromagnetic pulse should be looked at, they were beyond the scope of our work.

provides a means for describing essential PIC Program elements and defining the information required for the PIC Program's decision options.

In this report, we will

- Show how different sets of industrial countermeasures can provide the same post-attack capability.
- Develop a criterion for selecting industrial countermeasures.
- Describe a technical approach for satisfying that criterion.
- Highlight critical aspects of industrial protection, and recommend appropriate actions.
- Show that the time dependencies inherent in industrial countermeasures are crucial to this process.

These results are found using a treatment not complete nor exhaustive but one designed to show the essential facets of industrial protection in a clear and understandable way. More sophisticated and comprehensive analyses should be provided but only when uncertainties critical to the implementation of appropriate industrial countermeasures demand resolution.

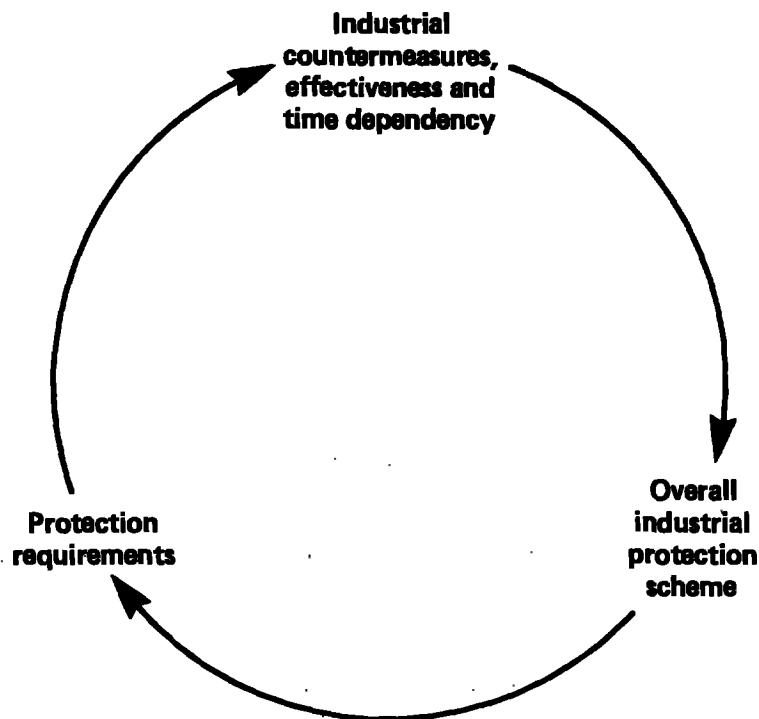


Figure 1. Interdependencies in the countermeasure selection process.

## POST-ATTACK INDUSTRIAL CAPABILITY

We protect industries against nuclear attack to ensure that predetermined critical levels of different industrial capabilities will continue to exist after the attack. This post-attack capability  $Q$  may be considered as consisting of two parts: the part of industry that survives the attack  $S$  and the part that recovers rapidly  $R$ . The simple expression for the post-attack capability is:

$$Q = S + R \quad (1)$$

This expression is valid whether we are concerned with our overall industrial capability or with that of a single industry; interdependencies of industries are included. The line on the graph in Fig. 2 shows the values of  $S$  and  $R$  that provide a fixed post-attack capability  $Q_0$ .

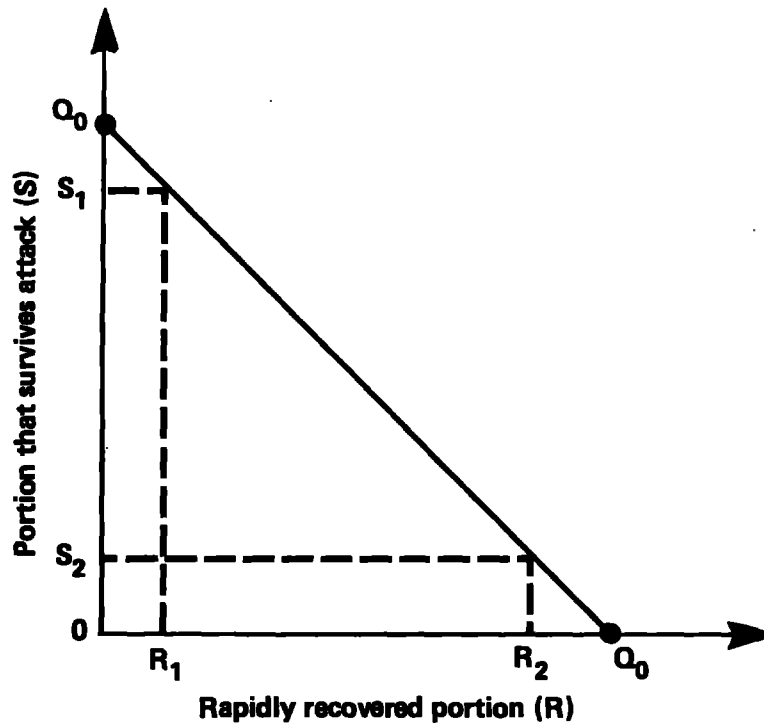


Figure 2. Two ways to obtain a given post-attack industrial capability,  $Q_0$ .

Figure 2 shows that we can obtain the same value for  $Q$  either by having a large portion of industry surviving the attack and a relative small portion that actually recovers, or vice versa:  $Q_0 = S_1 + R_1 = S_2 + R_2$ . This concept, though very simple, should guide our selection of industrial countermeasures. Combinations of countermeasures that improve survival and permit rapid recovery should be sought.

#### ESTIMATION OF INDUSTRIAL SURVIVAL

Another simple concept allows us to estimate the portion of industry that will survive an attack. The large rectangle in Fig. 3 represents the area of

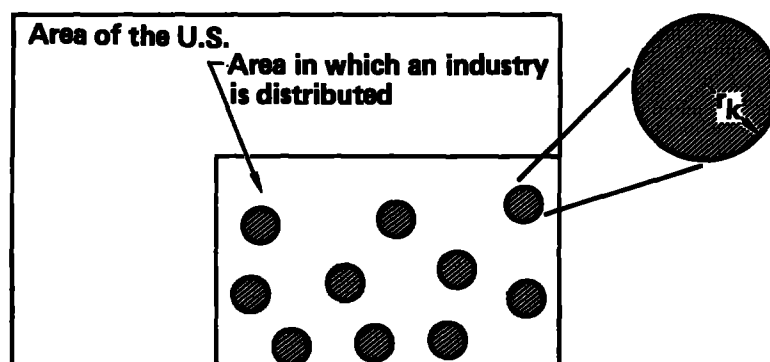


Figure 3. Estimating industrial survival. Industries in the shaded areas do not survive;  $r_k$  is the kill radius.

the United States. The smaller rectangle represents the area over which a specific industry is distributed. In a nuclear attack, there will be an area (a hole\*) centered at each weapon's ground zero, in which the industry will not survive the effects of blast and fire (i.e., is severely damaged or cannot be quickly repaired). Because the holes are small relative to the total area, the expected portion of industry surviving the attack is given by the expression:

\* The hole concept is not applicable to electromagnetic pulse and fallout because their effects are widely distributed. If unprotected, we must consider the holes overlapping (if vulnerable); if protected or not vulnerable we consider the holes as not existing.

$$S = \frac{(\text{Area of industry}) - (\text{Number of holes} \times \text{Area of each hole})}{\text{Area of industry}}$$

or

$$S = \frac{A_I - (N\pi r_k^2)}{A_I} \quad (2)$$

where  $A_I$  is the area occupied by industry, and  $r_k$  is called the "kill radius." (Actually this description may be in error, because the targeted area may not coincide with the area occupied by industry. If the two areas do not coincide, Eq. (2) provides a "worst case" estimate for S.)

This conceptual approach readily shows the influence of the pertinent variables. Figure 4 shows how various factors influence survivability. In short: increasing the number of warheads decreases survivability [Fig. 4(a)], but increasing the defensive capability [Fig. 4(b)], the dispersal area of industry [Fig. 4(c)], and protection against damage [Fig. 4(d)] increases survivability.

We can use Eq. (1) to obtain an estimate of survivability as a function of kill radius. Curves showing this relation are drawn in Fig. 5 for attacks of 500, 1000, or 2000 warheads, with an industry dispersed over either 1% or 10% of the area of the United States ( $3 \times 10^4$  and  $3 \times 10^5$  sq miles, respectively, out of a total area of  $3 \times 10^6$  sq miles).

Fig. 5 can be interpreted as follows:

If an industry can be protected against damage to within a kill radius of  $r_k$  miles (located on the abscissa), then the estimated industrial survival (for a specific attack and dispersal area) will be given by the ordinate value that intercepts the appropriate curve at that specific kill radius.

Or, it can be interpreted in the following way:

If a given percentage of industry (as shown by the value of the ordinate) is to survive a specified attack, then it must be protected from damage to the distance given by the abscissa value.

Notice that the curves are not functions of weapon yield. However, as the weapon yield increases, the kill radius becomes more difficult to limit. This concept has thus led us to a means for determining hardening requirements.

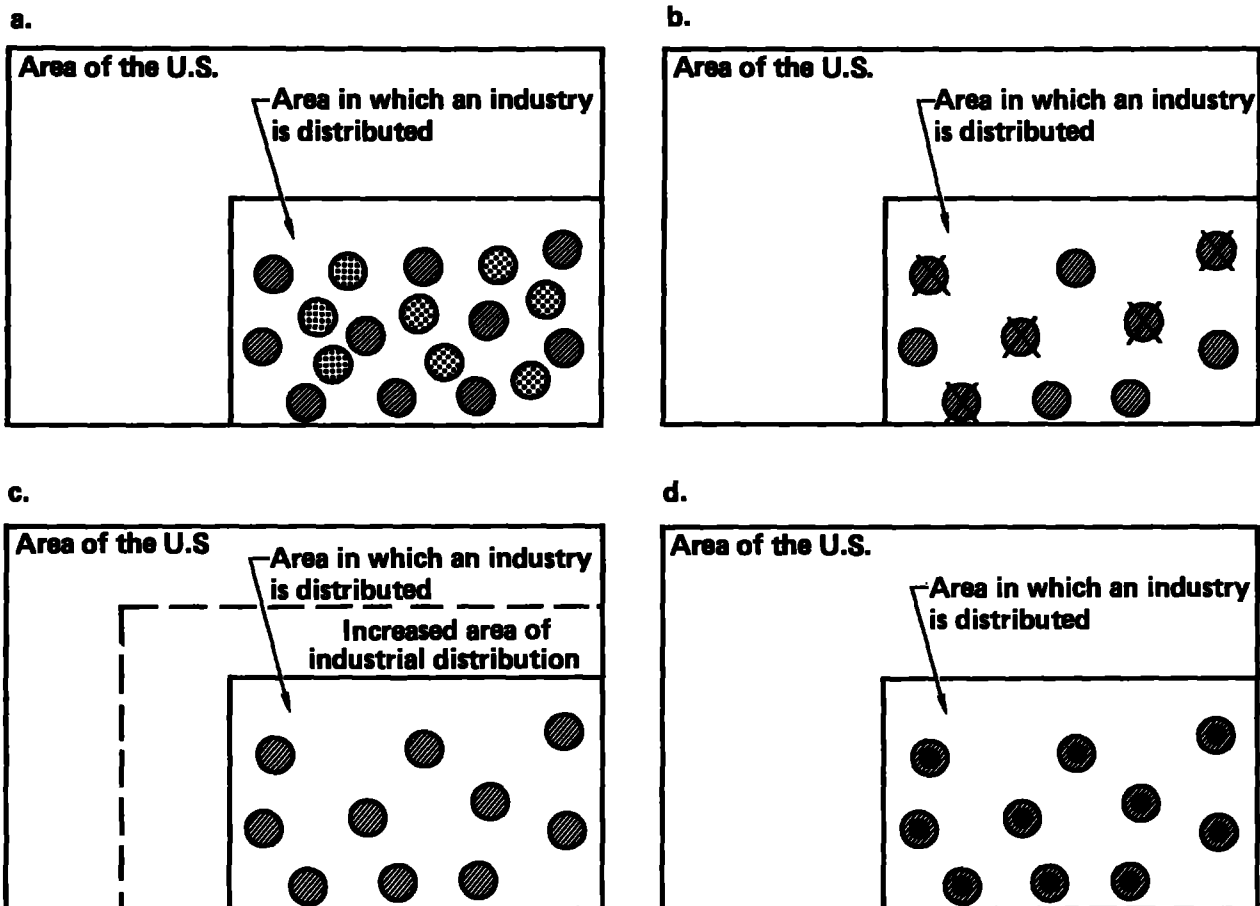


Figure 4. (a) The influence of the number of warheads on industry. (Adding more holes to those shown in Fig. 3 reduced the fraction of the surviving industrial area.) (b) The influence of a defensive capability. For the same number of warheads, an active ballistic missile defense would increase the industrial area that survives. (c) The influence of dispersal. For the same number of warheads, as the area occupied by industry increases, survivability increases. (d) The influence of protection. If we harden an industry, the area destroyed by a warhead decreases and survivability increases.



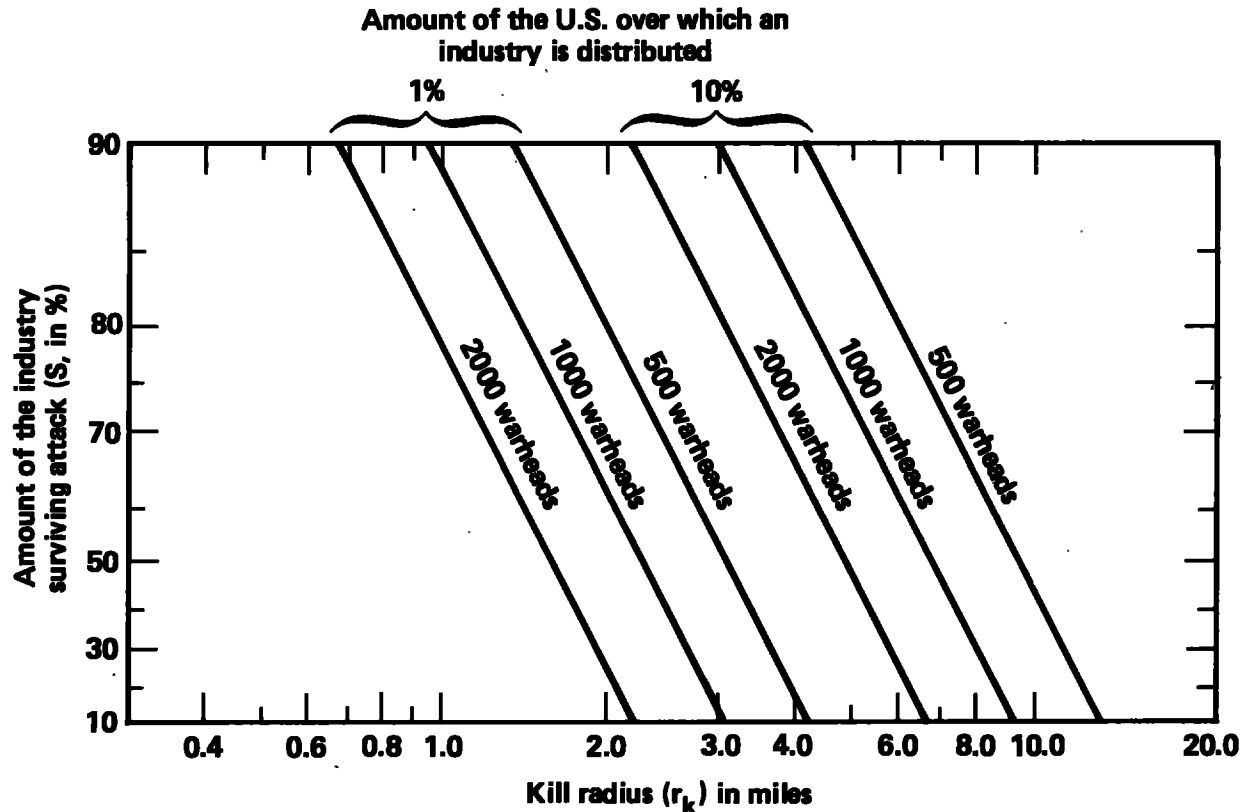


Figure 5. Industrial survival as a function of kill radius.

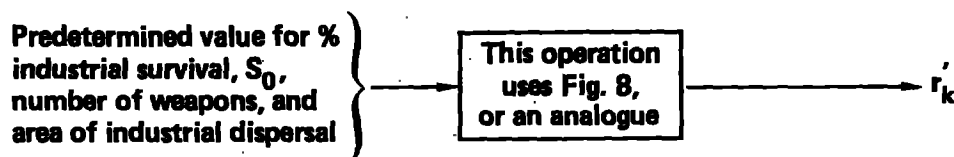
#### DETERMINING THE HARDENING REQUIREMENTS

Determining the blast hardening requirements is a two-step process, as shown in Fig. 6. In the first step, we must find the specific kill radius,  $r_k$ , for a predetermined value of industrial survival,  $S_0$ . Then, in the second step, we must determine the peak overpressure at the distance,  $r_k$ .

The graphs diagrammed in Fig. 5 are used to accomplish Step 1; for example, as shown in Fig. 7, assume that the attack consists of 1000 1-MT warheads and that the industry of concern is dispersed over 1% of the United States. Assume also that we have decided that it is necessary to retain 60% of this particular industrial capability. To accomplish this, we can see that the kill radius must be restricted to 1.9 miles or less.

Many references show the peak overpressure resulting from a nuclear detonation. We have used the book by Glasstone and Dolan<sup>1</sup> to select the altitude at which the peak overpressure occurs as the burst height varies. The peak overpressure at that altitude has then been plotted as a function of distance from ground zero. Curves generated in this manner, for 100-KT, 1-MT, and 10-MT weapons, are shown in Fig. 8. By intercepting the 1-MT graph (the

**Step 1:**



**Step 2:**

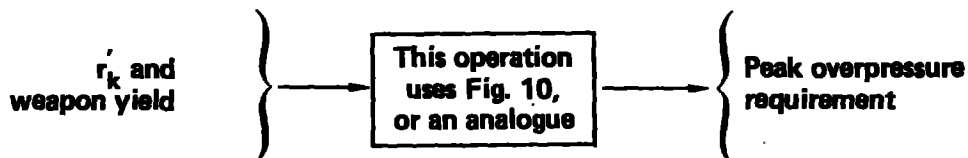


Figure 6. The process for determining overpressure hardening requirements.

assumed size of the weapons used in the attack) at a kill radius of 1.9 miles, we find that we must harden\* the industry to withstand an overpressure of 16 psi. The repeated application of this process allows us to obtain industrial survivability as a function of the degree of hardening. The curves illustrating this relation for a 1-MT weapon are shown in Fig. 9.

Overpressure is not the only hazard. Industry must also be protected against heat radiation, wind velocity and the secondary effects induced by

\* Used here in the broad sense of protecting against damage. Hardening thus need not physically change the item being protected, but it could provide an action that allows the item to survive the overpressure.

these hazards.<sup>2</sup> In Fig. 10, we show the intensity of heat radiation, wind velocity, and wind duration as a function of overpressure. These variables are functions of weapon yield. The curves shown are for a 1-MT weapon.

If we combine the curves in Fig. 10 with the overpressure value just derived (16 psi), we find that to ensure an industrial survival rate of 60% (with a dispersal area of 1%) against an attack of 1000 1-MT weapons requires that the industry be hardened to the following levels:

- Overpressure 16 psi
- Heat radiation 570 cal/cm<sup>2</sup>
- Wind velocity 430 mph
- Wind duration 3.4 s

These are rather stringent requirements, and we need to look for ways to reduce them.

#### DISPERSAL AND RECOVERY

Dispersal and recovery are two ways that can be used to reduce hardening requirements. We define these elements of protection as:

- Dispersal - The relocation of industry to distribute it over a greater area.
- Recovery - The incorporation of measures that will allow the quick reestablishment of industrial elements that failed to survive.

Figure 11 shows how dispersal can increase the allowable industrial kill radius, while maintaining the same percentage of survivability. Changing an industry's dispersal area from 1% of the area of the United States to 2% changes the allowable kill radius (for an industrial survival rate of 70%) from 1.7 to 2.4 miles, which in turn changes the hardening requirements. To illustrate that change, consider the kill radius in the previous example (1.9 miles). By doubling the dispersal area from 1 to 2%, the 70% survival radius is changed from 1.9 miles to 2.7 miles. In turn, the hardening requirements change, as follows:

	<u>1.9 miles</u>	<u>2.7 miles</u>
• Overpressure	16 psi	8.6 psi
• Heat radiation	570 cal/cm <sup>2</sup>	250 cal/cm <sup>2</sup>
• Wind velocity	430 mph	280 mph
• Wind duration	3.4 s	3.6 s

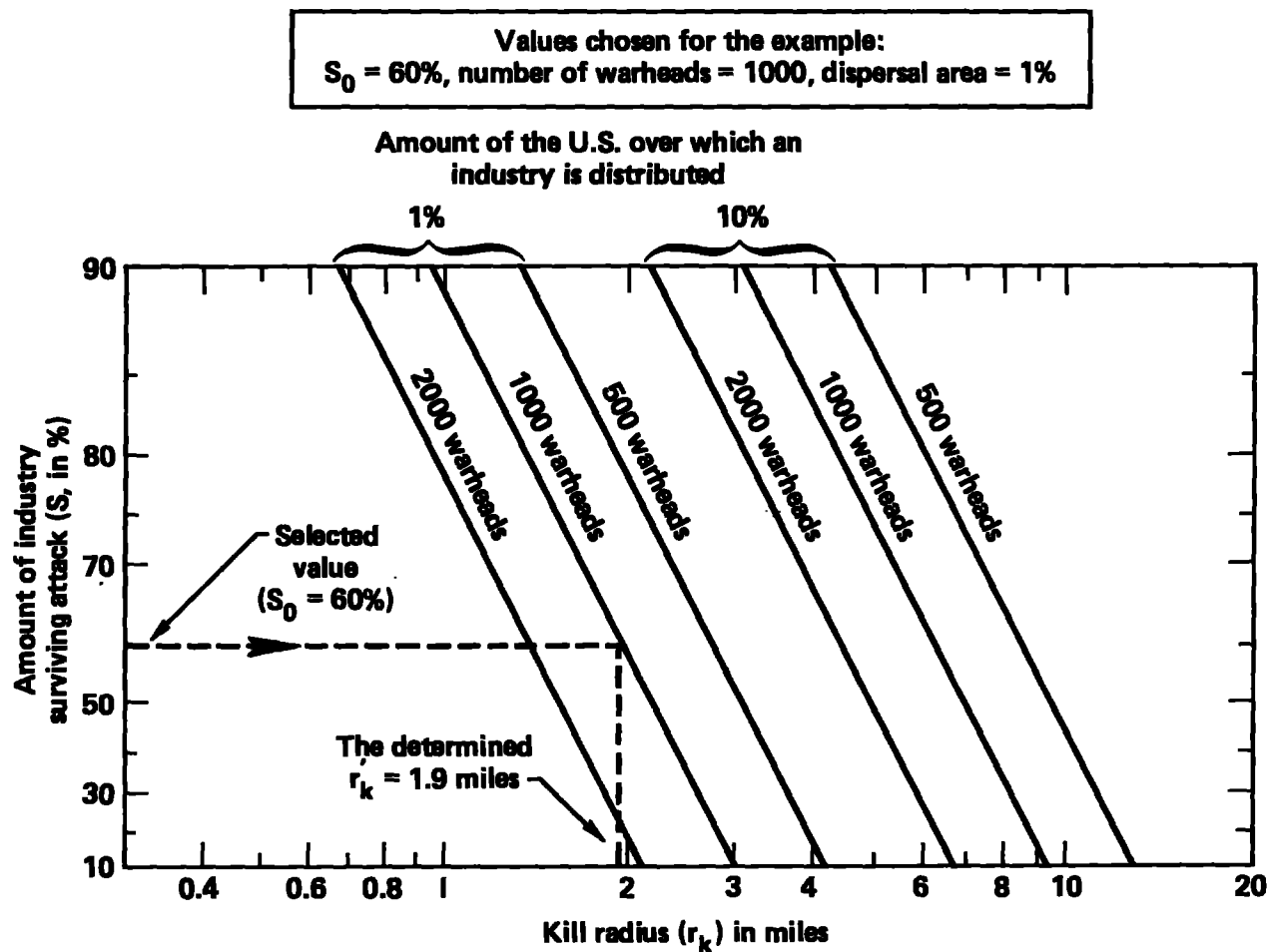


Figure 7. Example of Step 1. By using three specified parameters, we can find the allowable kill radius,  $r_k$ .

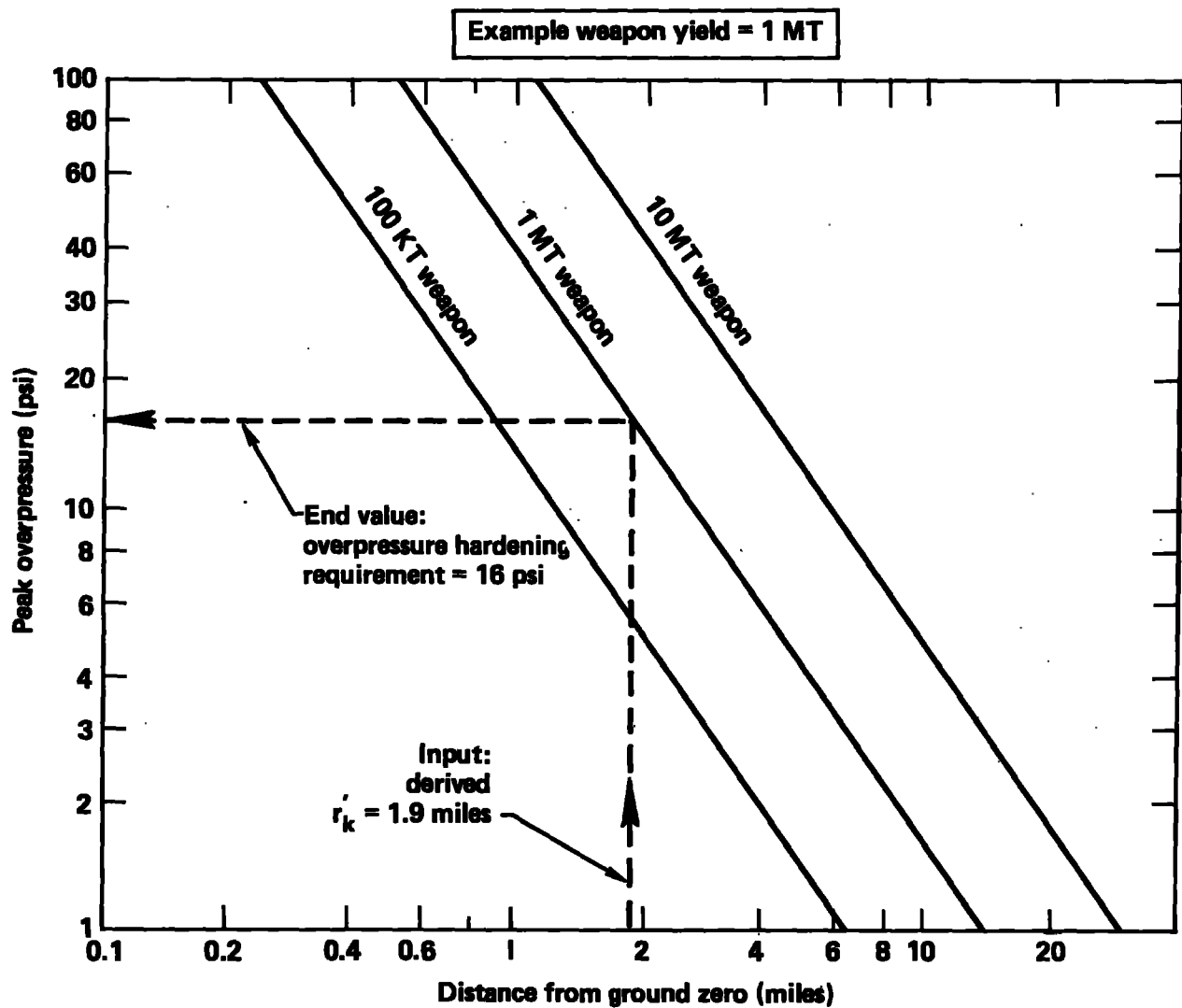


Figure 8. Example of Step 2. By using two specified parameters, we can find the peak overpressure hardening requirements.

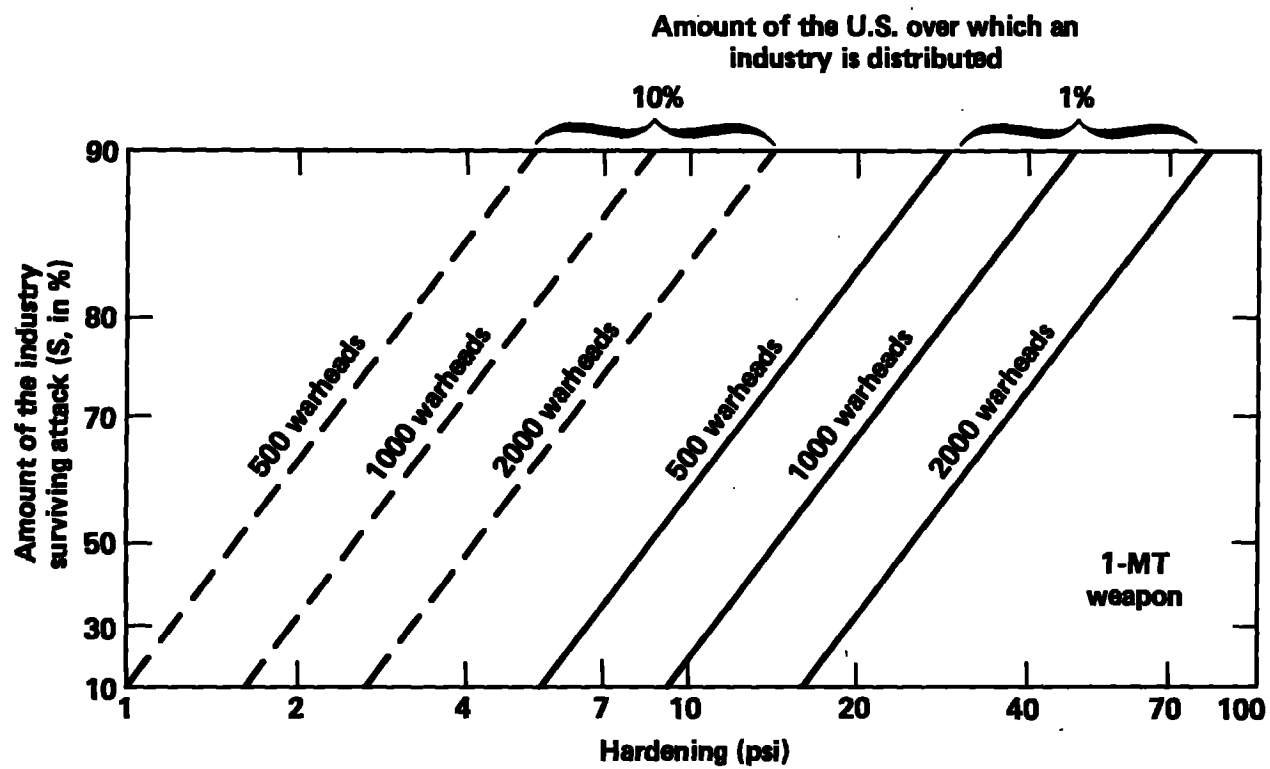


Figure 9. Survivability as a function of hardening.

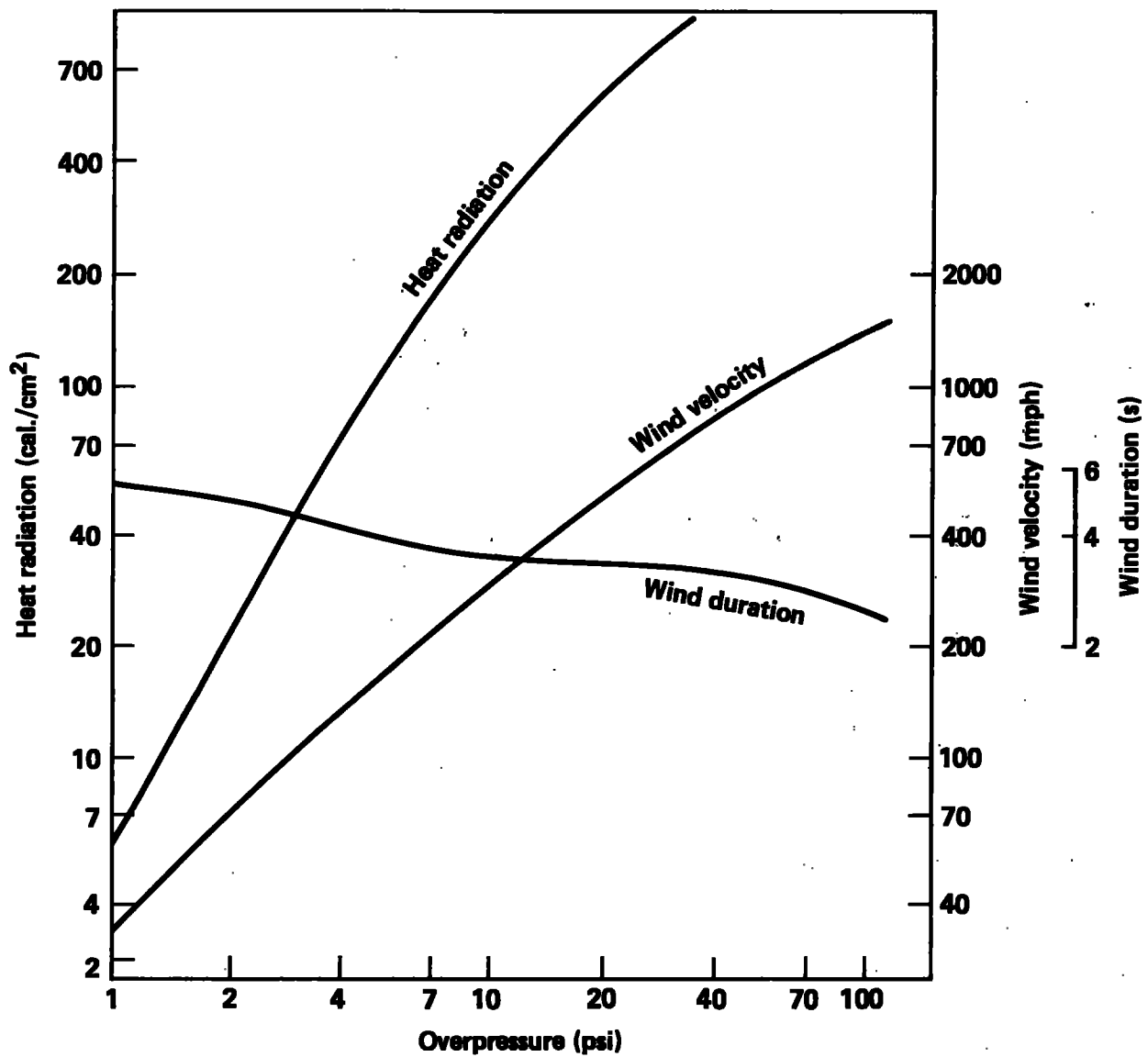


Figure 10. Other hardening requirements at a 16-psi overpressure from the previous example.

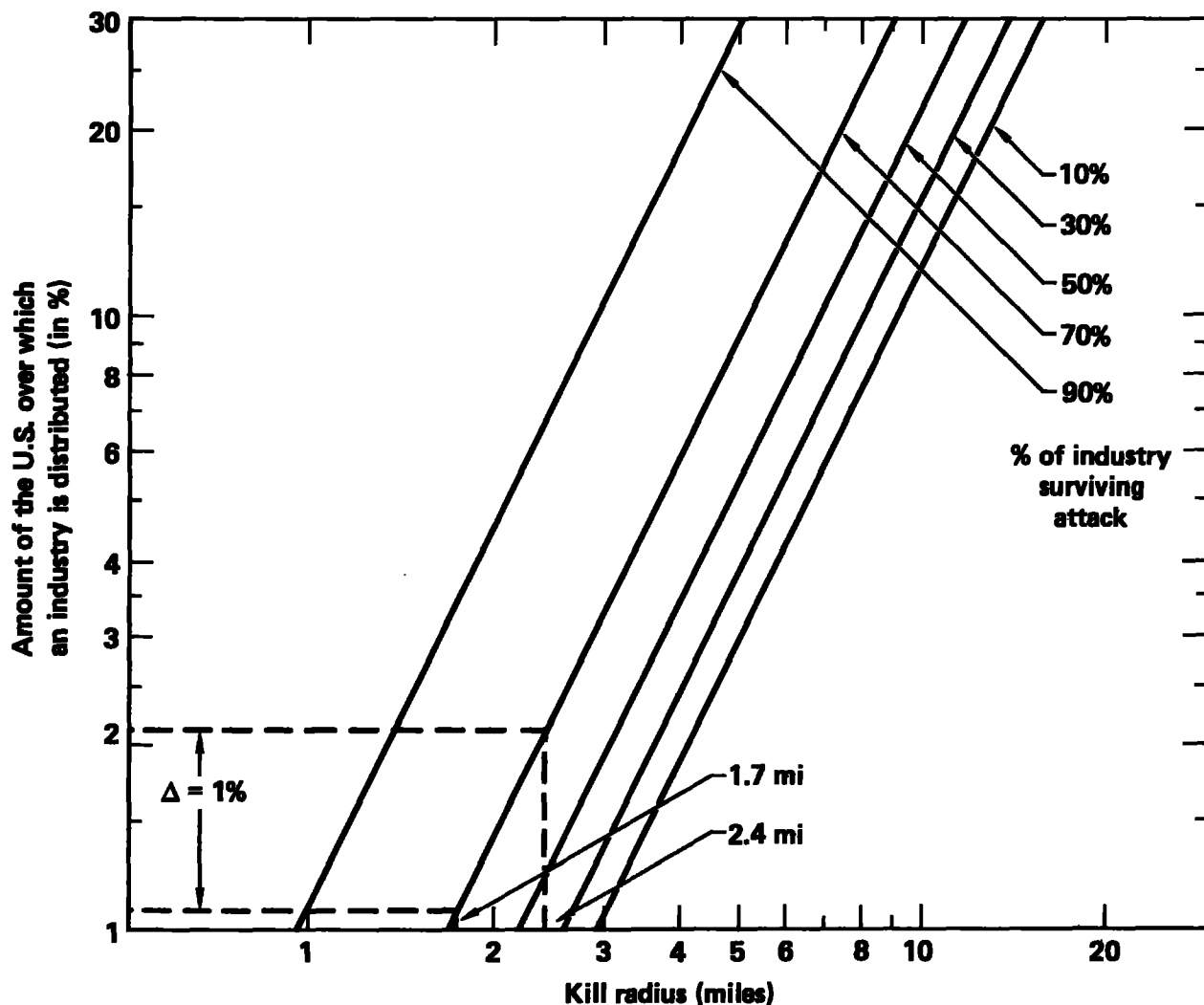


Figure 11. Using dispersal to increase the allowable kill radius.

These are significant changes.

A simple relation exists between the kill radius and dispersal areas:

$$\frac{r_{k(1)}^2}{r_{k(2)}^2} = \frac{A_{I(1)}}{A_{I(2)}} \quad (3)$$

The percentage of industrial survival will be the same if an industry is dispersed through an area of  $A_{I(1)}$  and is protected to a kill radius of  $r_{k(1)}$ , or if it has a dispersal area of  $A_{I(2)}$  and is protected to a kill radius of  $r_{k(2)}$ . The decision maker is now confronted with considerations as to whether it is better to disperse an industry through an area of  $A_{I(2)}$



and protect it to a distance of  $r_{k(2)}$ , or to protect it to a distance of  $r_{k(1)}$ . Apparently, a judicious choice of industrial dispersal and hardening will provide an optimized protection scheme for industrial survival.

But, perhaps the best philosophy is not to harden an industry to a specific kill radius to obtain a high survival rate, but rather to harden the industry to a lesser degree (and accept the decreased industrial survival rate), while instituting other countermeasures that will permit the industry to recover rapidly. Such countermeasures include:

- Overhardening specific critical industrial elements.
- Providing spare dispersed facilities.
- Maintaining a dispersed inventory of critical elements.
- Stockpiling materials in remote locations.
- Planning and providing resources for intensive repair measures.

It is now apparent that the best set of countermeasures for a specific industry will consist of some combination of hardening, dispersal, and recovery. As one might suspect, that combination (as will be shown), is different for each industry.

### SELECTION OF INDUSTRIAL COUNTERMEASURES

In order to select an optimal set of industrial countermeasures, it is first necessary to establish the criterion. A general statement of the criterion is, "To provide needed post-attack industrial capability at minimum cost."

Let us now examine this statement in more detail. Its salient points are

- There is a minimum post-attack industrial capability that must be maintained for the entire U.S. industrial complex. (A post-attack industrial capability that is less than that minimum value would have a catastrophic effect on our socio-economic systems.)
- The overall industrial capability of the U.S. is a complex aggregate of the capabilities of individual industries.<sup>3-5</sup> (An industry requires support from other industries, and it in turn may support other industries.)
- A minimum overall industrial capability implies that minimums also exist for individual industries, but these minimum values will

differ. (Industries are interdependent; the influence on the socio-economic system differs for each industry.)

It is therefore concluded that

- The criterion for selecting industrial countermeasures is to obtain the minimum required post-attack capability for each industry, at a minimum cost:

$$\text{Min}(\$Total) = \text{Min}(\$Dispersal + \$Recovery + \$Hardening)$$

In our examination of specific industries we can expect that the hardening cost will decrease, as the kill radius we permit to exist increases. A set of curves representing the hardening costs for the various nuclear-weapon hazards is shown in Fig. 12. The total hardening cost is the composite of the costs required to harden for each hazard. When a countermeasure protects against more than one hazard, the costs are shared. The actual curves are expected to have a shape similar to those in Fig. 12. The actual values and the differences between curves will depend on the characteristics of the individual industries.

We can also present dispersal costs in terms of kill radius, as shown in Fig. 13. These curves assume a linear relation between the cost of the dispersal (\$Dispersal) and the increase in the dispersal area. The proportionality constant  $k$  is a quantity equal to the cost of increasing the dispersal area by  $3 \times 10^4$  sq miles. The curves assume that the industry was originally dispersed over 1% of the U.S. ( $3 \times 10^4$  out of  $3 \times 10^6$  sq miles) and that an attack consists of 1000 1-MT warheads. The actual dispersal costs are not shown on these curves. Such costs have not been evaluated, and are very dependent on the individual industry for which they are evaluated.

Because both \$Hardening and \$Dispersal can be shown to be functions of the kill radius, their sum can be analyzed to find a minimum value, as shown in Fig. 14. The solid curves represent the costs for hardening and dispersal for achieving various percentages of industrial survival. The dashed curves are the summed costs for each of these percentages.

Figure 15 shows how recovery countermeasures enter into the selection process. We begin by establishing the post-attack industrial capability  $Q_0$ , that we need [Fig. (15a)]. There are many combinations of values of

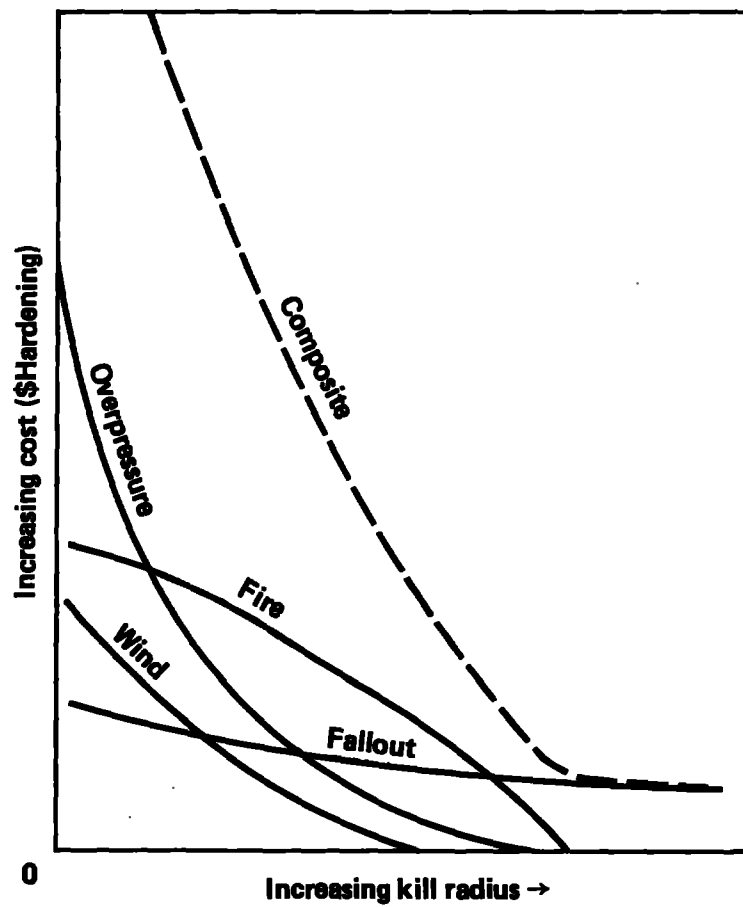


Figure 12. Hardening costs as related to the planned survivable kill radius.

recovery  $R$  and survival  $S$  that will provide a particular  $Q$ . For each pair, there is a survival cost [Fig. 15(b)] and a recovery cost [Fig. 15(c)]. When the sums of these costs are graphed [Fig. 15(d)], a minimum cost is found. The percentage of survival  $S_0$  at this minimum cost position was obtained by using a prescribed set of countermeasures for survival and dispersal; thus, we can determine which hardening and dispersal countermeasures are needed to obtain a minimum cost. We will also know, from  $R_0 = Q_0 - S_0$ , what recovery countermeasures will provide the recovery. In this manner we can obtain an optimized set of industrial countermeasures.

We have shown how an optimum set of countermeasures may be selected. In reality the process is, of course, more difficult than illustrated. Nevertheless, the general mechanics for the selection will be much the same. It is important to view costs differently if they are expended before a crisis, during an actual crisis period, during a false crisis with no attack

resulting, or after an attack. Also, the effectiveness of countermeasures, and thus the resulting mix of survival, dispersal, and recovery measures, depends on when actions associated with the countermeasures are executed in the attack scenario. Incorporating these factors in the selection process will lead to the "best" set of countermeasures for industrial protection. An understanding of the selection process and the needed optimal supporting information defines the technical approach required for countermeasure selection.

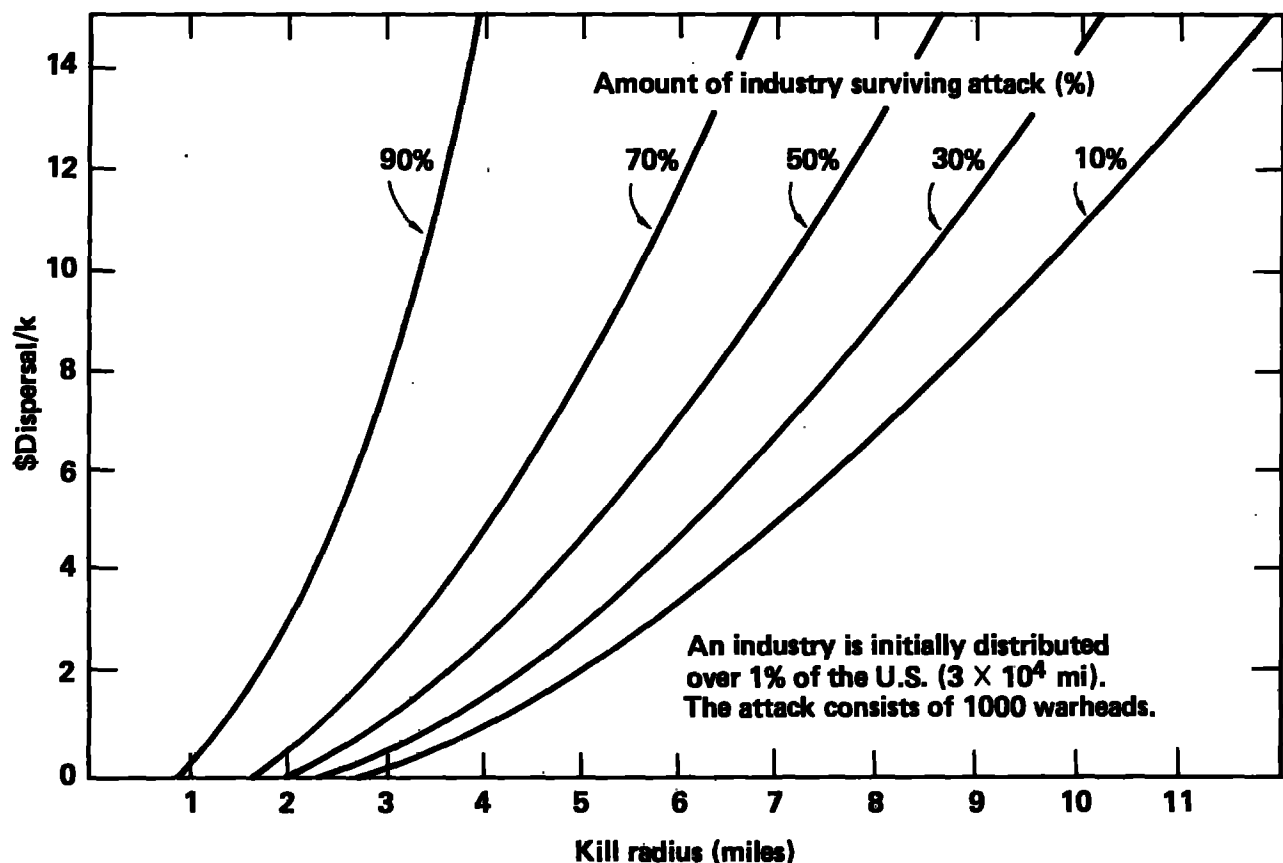


Figure 13. Dispersal costs as a function of the planned survivable kill radius.

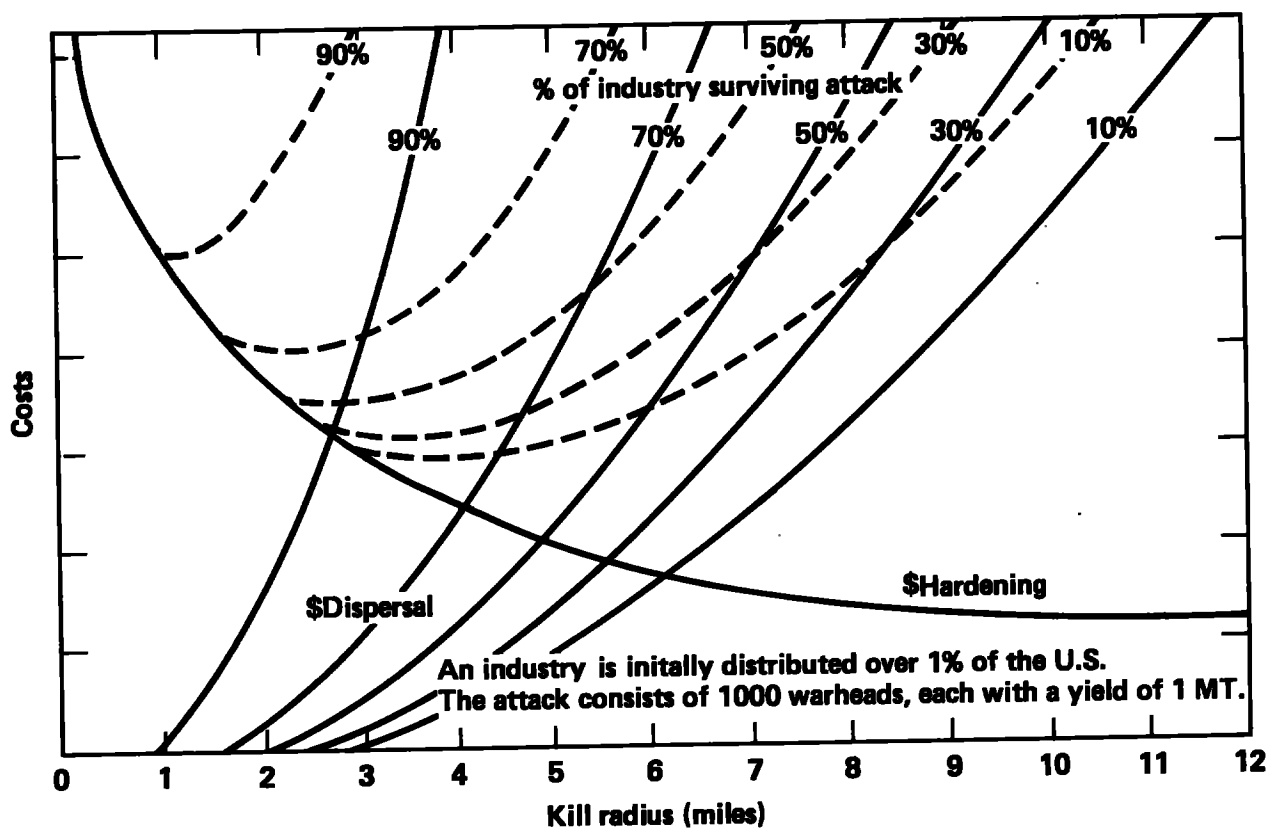


Figure 14. Costs to increase survivability as a function of the planned survivable kill radius.

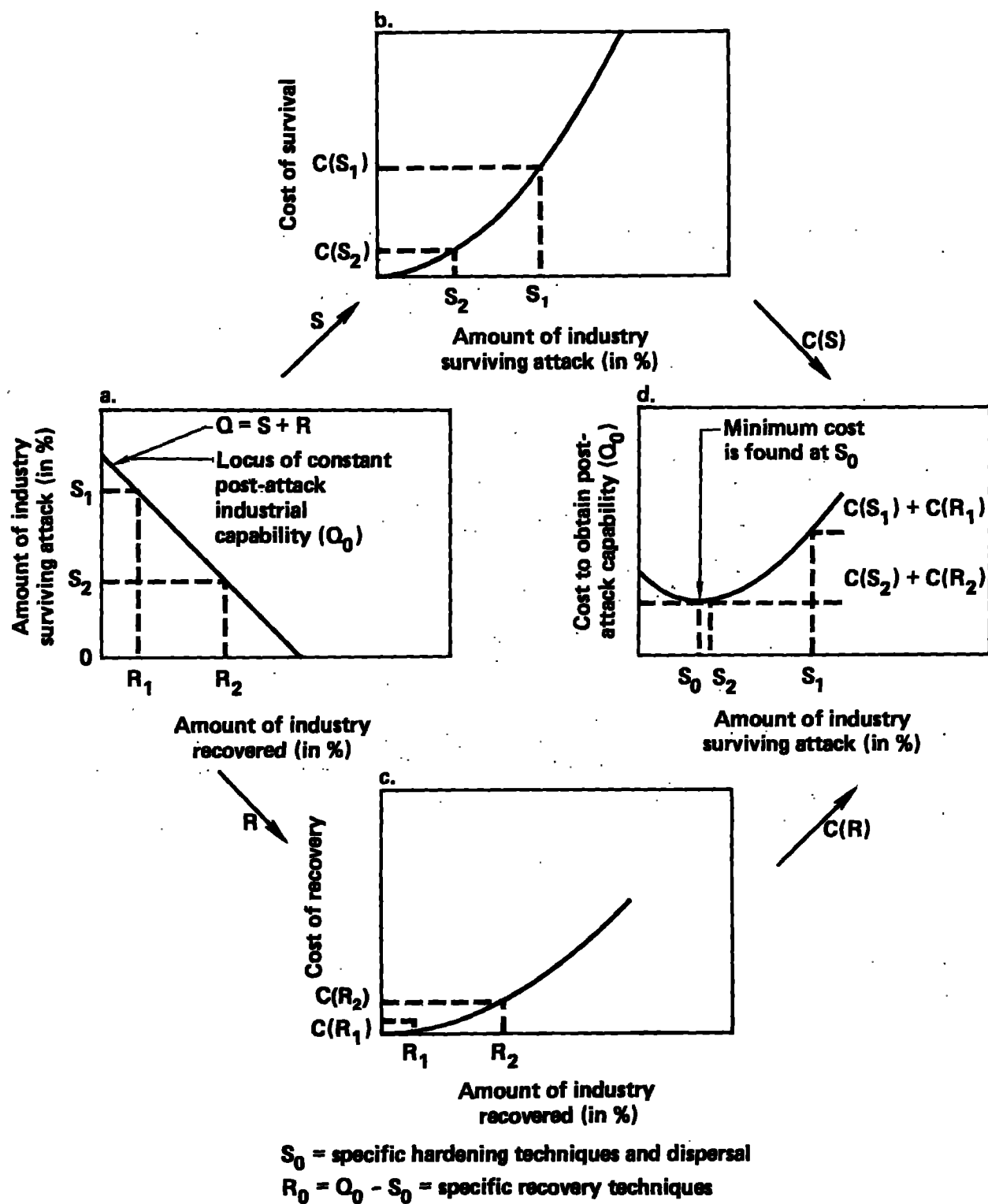


Figure 15. Illustration of the concept by which countermeasures are selected.

## TECHNICAL APPROACH

There are five steps in the technical approach for determining an optimal industrial countermeasures scheme:

1. Identify and characterize the industry.
2. Characterize the identified countermeasures.
3. Evaluate the costs and effectiveness of the countermeasures for each industry.
4. Evaluate industry-specific factors that will influence countermeasure selection.
5. Select the best scheme, based on the criteria of effectiveness and costs.

The first and second steps, respectively, characterize the individual industries and the countermeasures identified as potential candidates for those industries. To "characterize" them means to list and evaluate those characteristics relevant to the solution of the problem, which in this case is the selection of industrial countermeasures. To be sure all characteristics are included, we must first ask, "What is the countermeasure?"

A "countermeasure" is defined as the complete set of actions and resources used to accomplish a specific protection objective. Each is needed to define the countermeasure. An example is given in Fig. 16, which has as its objective the protection of personnel against the various hazards resulting from a nuclear detonation. These actions and resources include

- Develop and execute procedures.
- Maintenance, direction, and control.
- Leadership and training.
- The shelter itself.

The data sought for characterizing industries and countermeasures are values for variables which help determine the effectiveness and costs of the countermeasures, as applied to specific industries. We have already suggested that both the effectiveness and cost considerations are related to the attack scenario. The scenario is shown in Fig. 17, along with examples of critical times that must be considered in characterizing both the industry and the effectiveness of the countermeasures.

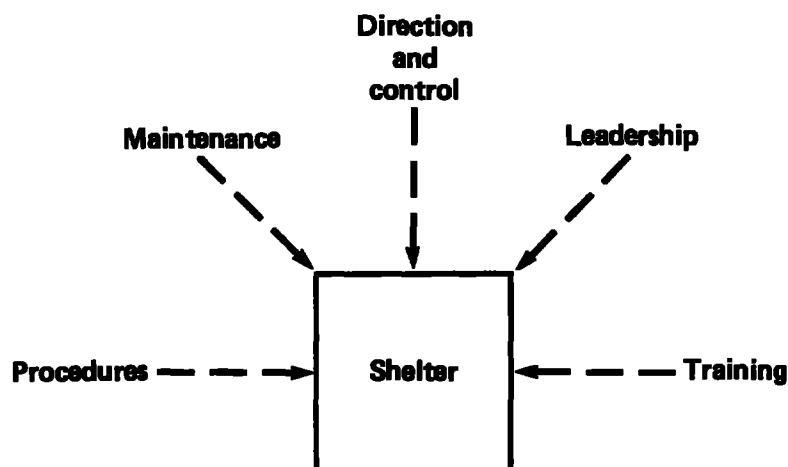
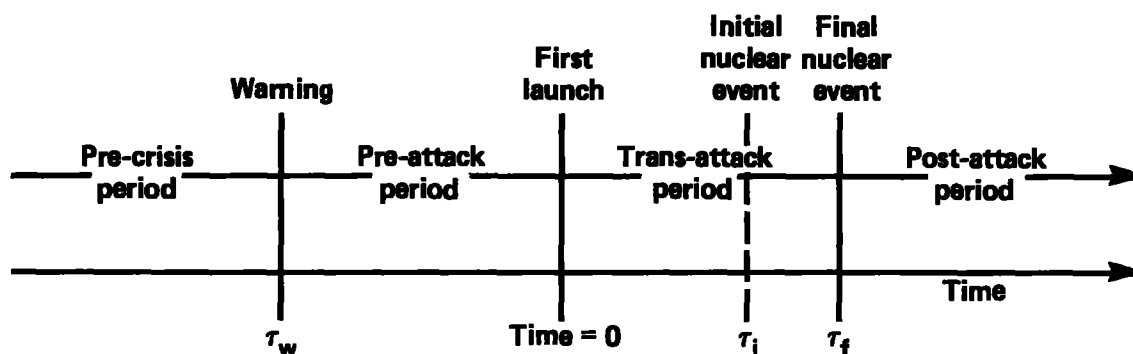


Figure 16. An example of a comprehensive countermeasure.



Example:

$\tau_w$  — 7-10 days prior to the time of initial weapons launch

$\tau_i$  — 30 minutes following the initial launch of weapons

$\tau_f$  — 30 minutes to a few days following launch

Figure 17. Time phases in an attack scenario.

The information characterizing an industry, which is needed for the first step of selecting an optimal set of industrial countermeasures, is illustrated in Fig. 18. An "X" in the table stands for a generalized entry about certain specific industrial elements. Columns 1 through 4 identify the susceptible elements of the industry, the nuclear hazard that they are susceptible to, the inherent hardness of the element, and the effect created by the hazard. Columns 5 through 8 provide information about industry-specific parameters



that contribute to the costs and effectiveness of the countermeasure options. Columns 9 through 11 identify the potential means of protection, the resources required for this protection, and the availability of those resources.

**Step 1**

Industry										
Potentially susceptible elements	Nuclear hazard	Susceptibility level of industrial element to hazard	Effect created by hazard	Size of element	Location of element	Mobility of element	Fragility of element	Countermeasures to protect the element		Resource availability for the countermeasure
								Potential means of protection	Resources required	
X	X	X	X	X	X	X	X	X	X	X
								X	X	X
								X	X	X
X	X	X	X	X	X	X	X	X	X	X
								X	X	X

Figure 18. A sample industrial characterization that would be used to identify the appropriate countermeasure.

The second step in selecting industrial countermeasures is to characterize them. When the industrial information of Step 1 is coupled with the countermeasure characterization, the costs and effectiveness of the countermeasures can be evaluated. Figure 19 is a matrix indicating the information needed for countermeasure characterization. Listed first is general information: the countermeasure and the element being protected, the hazard and effect being combatted, and the level of protection gained by using the countermeasure. We then identify the actions and resources of the countermeasure for each time interval in the scenario. Some countermeasures are useful against more than one hazard, so their costs are split among those hazards. Each countermeasure may also require support from some other segment

**Step 2**

Countermeasure Options					
	General	Pre-crisis period	Pre-attack period	Trans-attack period	Post-attack period
Countermeasure/item	X				
Hazard/effect	X				
Level of protection	X				
Actions		X	X	X	X
Resources		X	X	X	X
Shared costs		X	X	X	X
Utility		X			
Support needs		X	X	X	X
Factors	X	X	X	X	X

Figure 19. Countermeasure characterization for a specific industry.

of industry or society. These support requirements must be identified, since they may detract from the effectiveness of (or have some other impact on) another emergency function. The concept of utility is also important, particularly in the pre-crisis period. Those actions or resources that satisfy a countermeasure requirement, and that also satisfy a peacetime function, are preferred to those which do not do both. Finally, the characterization of a countermeasure should include all of the factors influencing its effectiveness, or the effectiveness of other countermeasures. Examples of such factors include the time needed to execute a countermeasure, its level of complexity, the amount of training that is required, mutual exclusivity, and competition for resources.

Steps 1 and 2 are the information collection phase of the selection process. Most of the information needed is already available, but it is not in a format that permits comparative analyses. Having collected this information and displayed it in a compatible format, it is necessary to aggregate this information so that factors fundamental to the decision process can be evaluated. Steps 3 and 4 provide that evaluation process. Figure 20 shows the inputs and outputs in the evaluation process. The outputs are used

### Steps 3 and 4

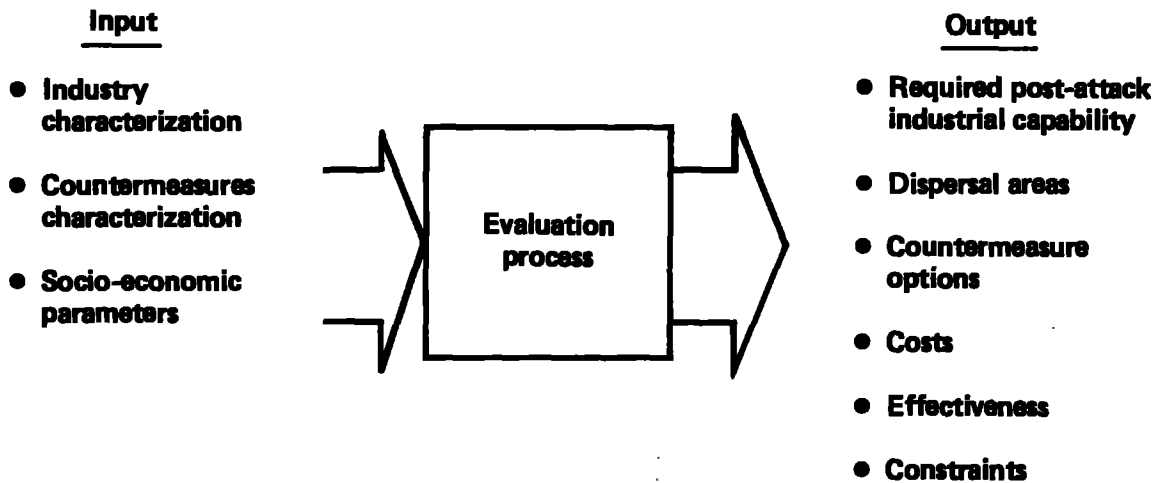


Figure 20. Factors evaluation for time-dependent countermeasures.

as inputs to the decision process, which provides the optimal set of industrial countermeasures, illustrated as Step 5 by Fig. 21.

Briefly, the approach that will provide an optimal set of industrial countermeasures starts by identifying the critical industries contributing to our industrial complex. Each industry is then examined with regard to element susceptibility and the factors influencing the costs and effectiveness of possible countermeasures. Then, possible countermeasures are identified and (for each industry) each identified countermeasure is listed, along with the actions and resources required for each of the time intervals in the attack scenario, and the information pertaining to each countermeasure's usability,

cost, and effectiveness. Next, we must determine the effectiveness of the countermeasures for each industry, with respect to specified levels of protection and costs. We must also determine the post-attack capability needed by each industry, and its dispersal area. The decision process then weighs the costs of countermeasures providing hardening, dispersal, and recovery, to determine the optimal set. Since each countermeasure has a potential for contributing toward a specified degree of protection (to harden, disperse, or recover), evaluating its effectiveness and making a decision will, for the most part, be judgemental. However, by using the approach described in this paper, the decision maker will have the information needed for making a good and defensible selection of industrial countermeasures.

#### **Step 5**

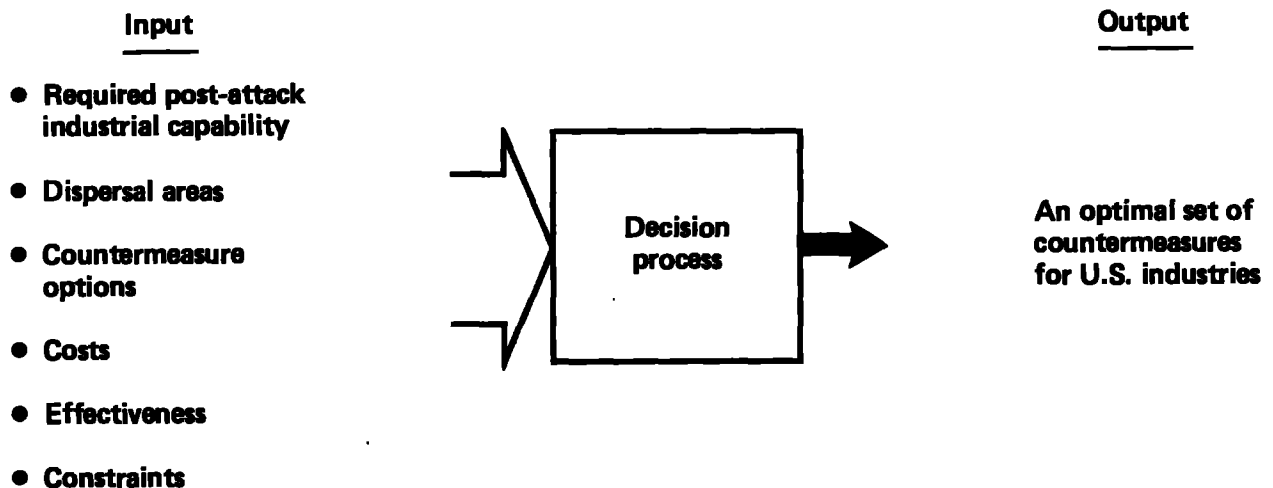


Figure 21. Final selection of industrial time-dependent countermeasures.

#### **CONCLUSIONS**

We have presented in this paper a technical approach that can lead to the selection of an optimal set of countermeasures for protecting U.S. industry

against a nuclear attack. The approach is based on a concept that is shown to be technically sound. Paramount to the selection process are

- The identification of critical industries and the capability that will be required from them in a post-attack economy.
- The characterization of these industries and the applicable countermeasures. These characterizations will permit selecting an optimal set of industrial countermeasures based on time dependencies, as evaluated for the individual industries.
- Cost minimization, which assumes that only limited Federal monies will be made available for this process.

#### RECOMMENDATIONS

FEMA might consider the basic arguments and the approach in this paper as a guide for the PIC Program and for determining industrial countermeasures. The approach, if accepted by FEMA, could be executed for critical industries, and the results could be supplied to those industries.

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2342D

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May 1984, 29 pp (UNCLASSIFIED)

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The work was performed as part of FEMA's Protection of Industrial Capability (PIC) Program.

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